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Loading Effect on Tire Noise Radiation

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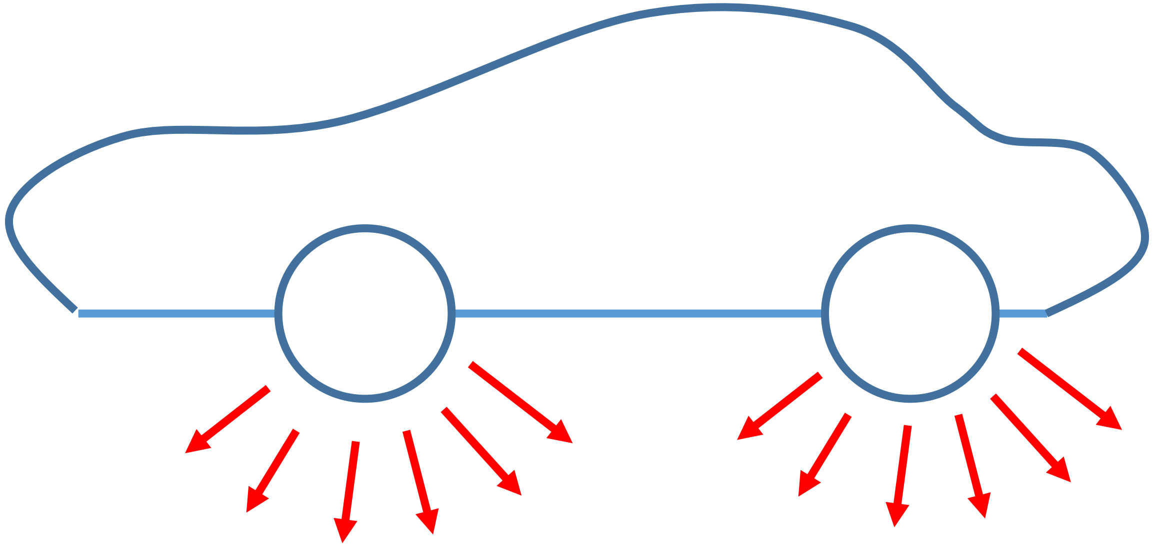
I. Introduction



Heavier -> Louder ?

Yes

No

Yes & No
- Frequency dependent

II. Testing facility

Tire Pavement Testing Apparatus (TPTA)

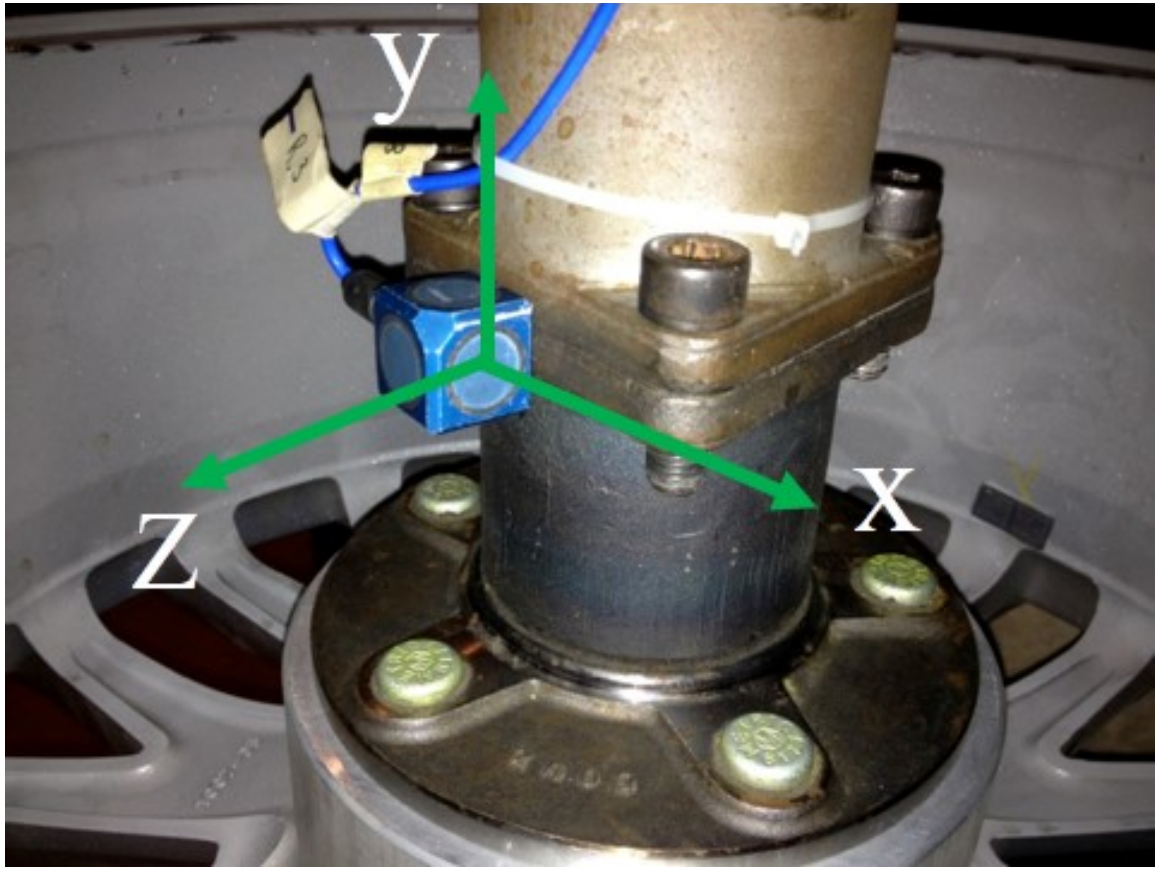
- Sits inside a semi-anechoic chamber
- Has a radius of 2.2 m
- Six different concrete pavement surfaces around the circumference
- Adjustable arm length for applying different loads
- Speeds up to 50 km/hr

II. Testing facility

Phase matched microphone pair

- Mounted according to OBSI measurement standard
- Microphone spacing 16.45 mm, which ensures <1 dB finite difference error up to 3.8 kHz

II. Testing facility



Tri-axial accelerometer mounted on the rigid hub

- ❖ Z-direction – normal to the pavement surface
- ❖ *Y*-direction – axial direction
- ❖ *X*-direction – tire travel direction

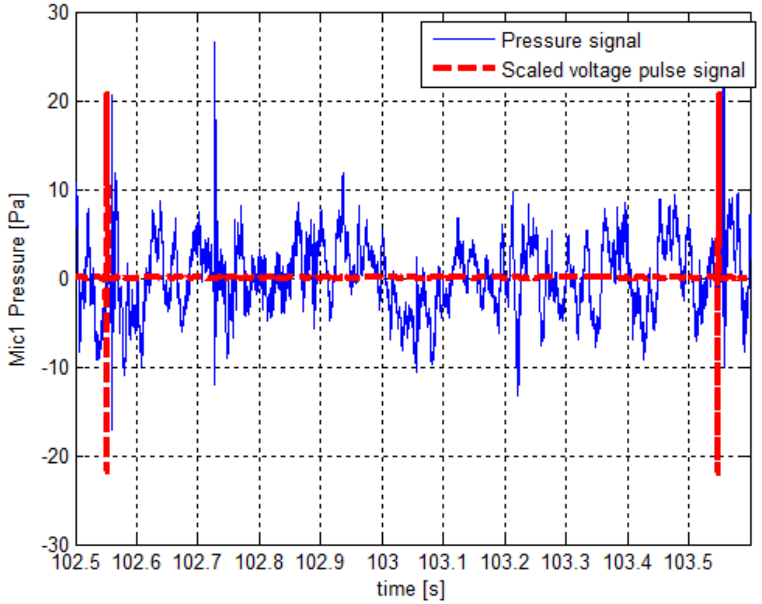
II. Testing facility

Deep grooves	Shallow grooves
Smooth	

Tested surface types

III. Testing procedure and data processing

Magnetic trigger:
A magnetic pulse is generated when the trigger passes the designated gap location on each revolution



III. Testing procedure and data processing

I. Tire inflation pressure: 35 psi (no loading condition)
II. 700 lbs load applied for 5 minutes warmup @ 30 mph (48 kph)
III. Start testing with 700 lbs load @ 30 mph for 6 minutes to obtain 300 samples
IV. Switching load to 900 lbs, 500 lbs, 800 lbs, 600 lbs for each load case test at 35 psi inflation and 30 mph speed

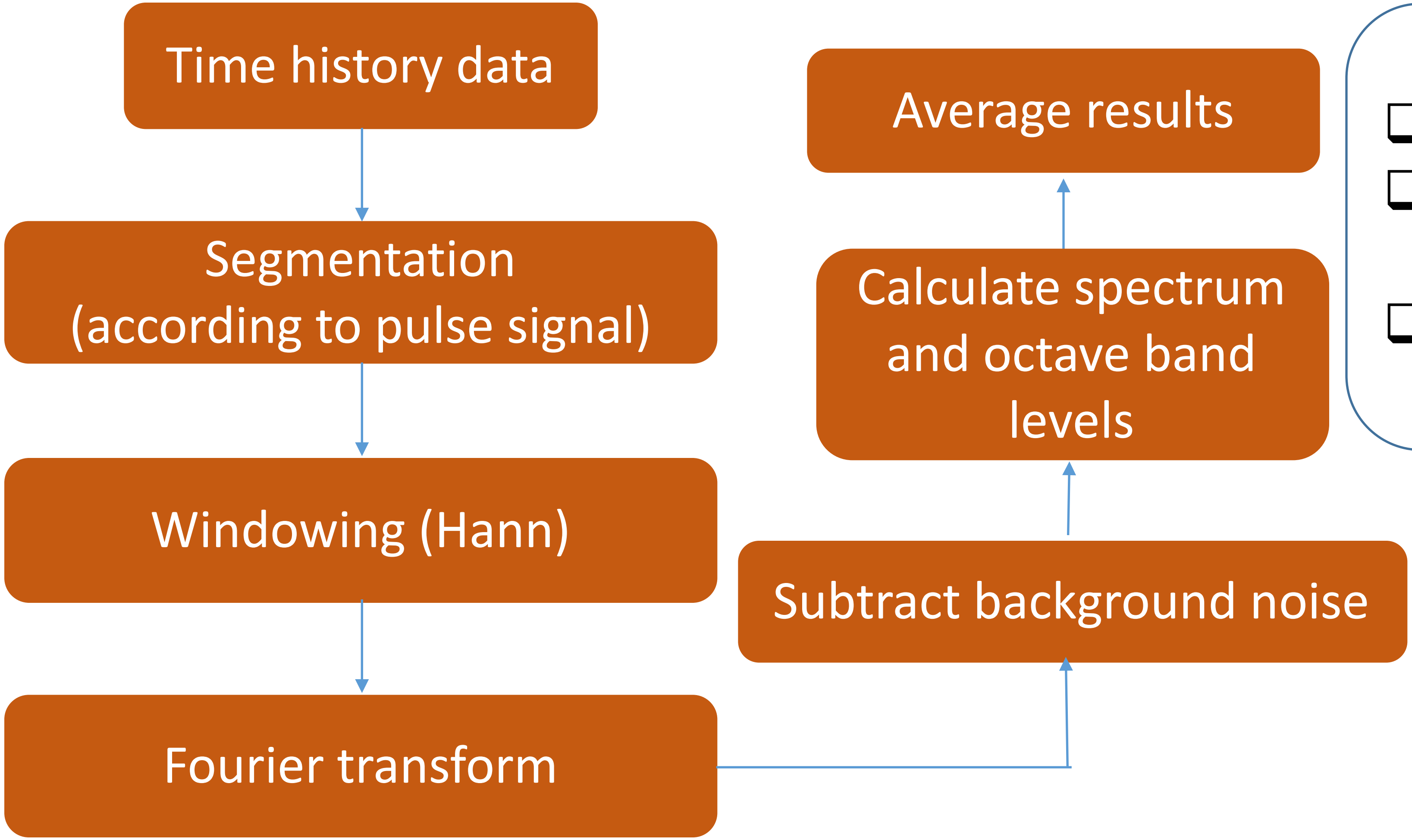
(Interval between each load condition is usually 1 minute, may take longer for cooling if motor temperature sensor indicating overheat)

III. Testing procedure and data processing

Tested tires

Tire Number	Diameter[in]	Width [mm]	Aspect ratio
A	16	215	0.60
B	17	215	0.55
C	18	225	0.45
D	19	245	0.45

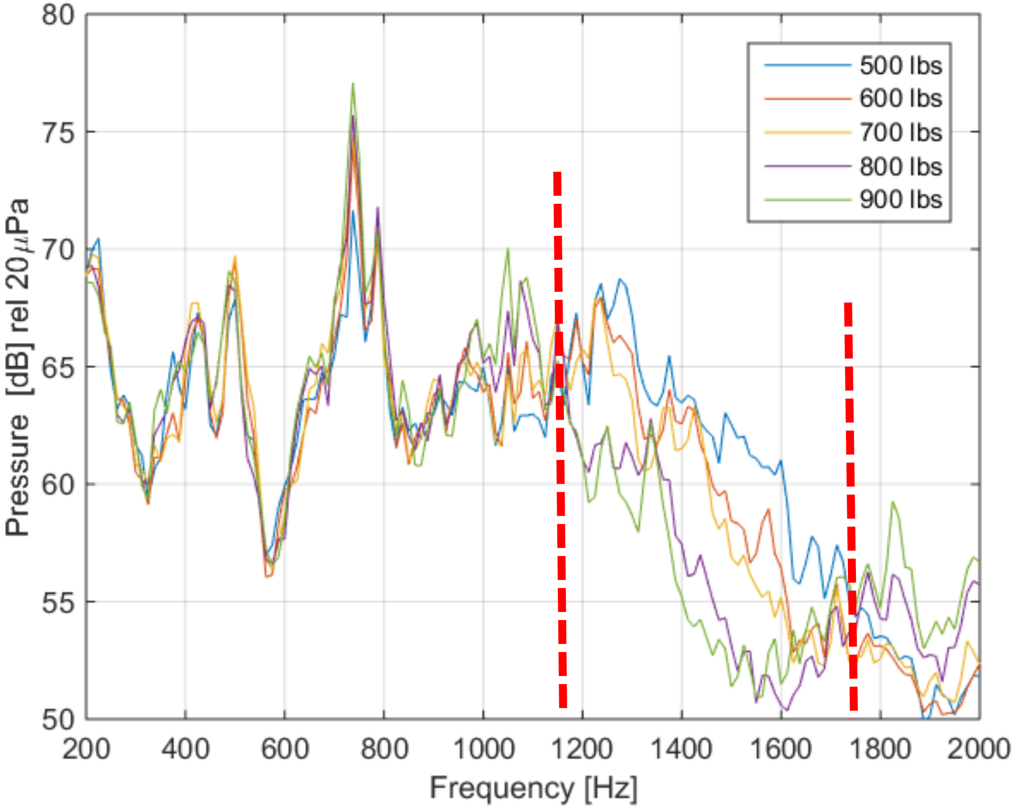
III. Testing procedure and data processing



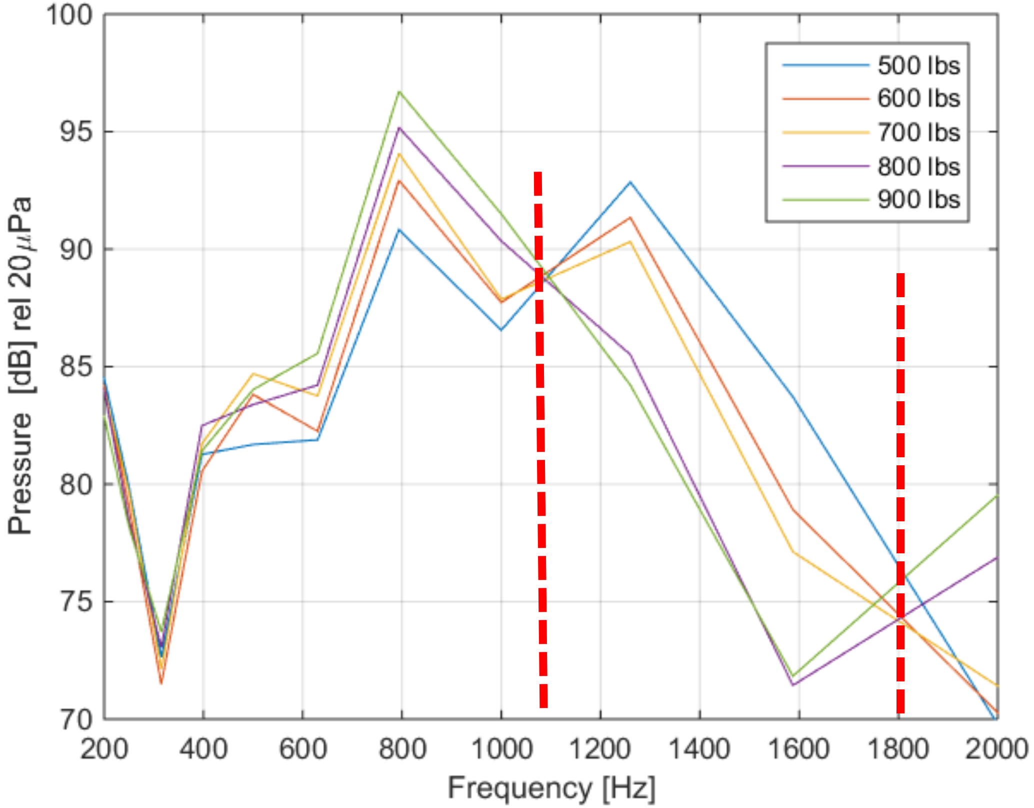
- Segment length: 80ms
- Sampling frequency: 16384 Hz
- Number of averages: 300

IV. Results

Pavement surface 1 (rough): Tire D (empty cavity) (a) spectrum (b) third-octave levels



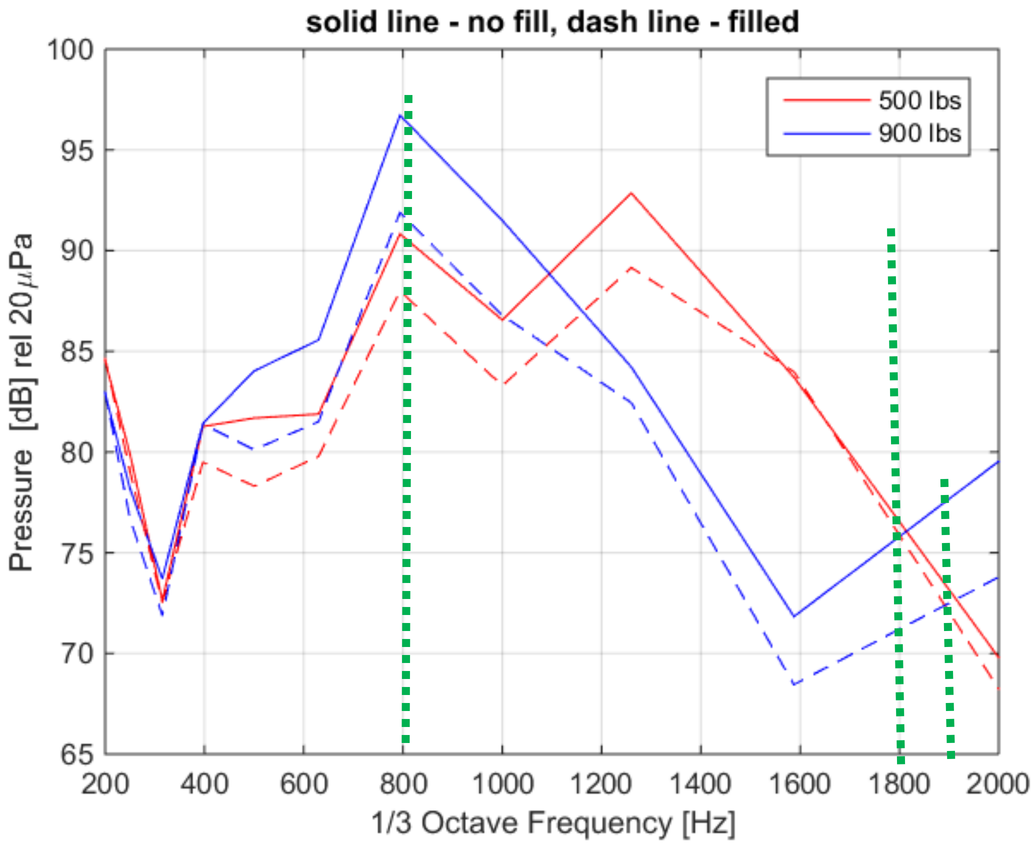
(a)



(b)

IV. Results

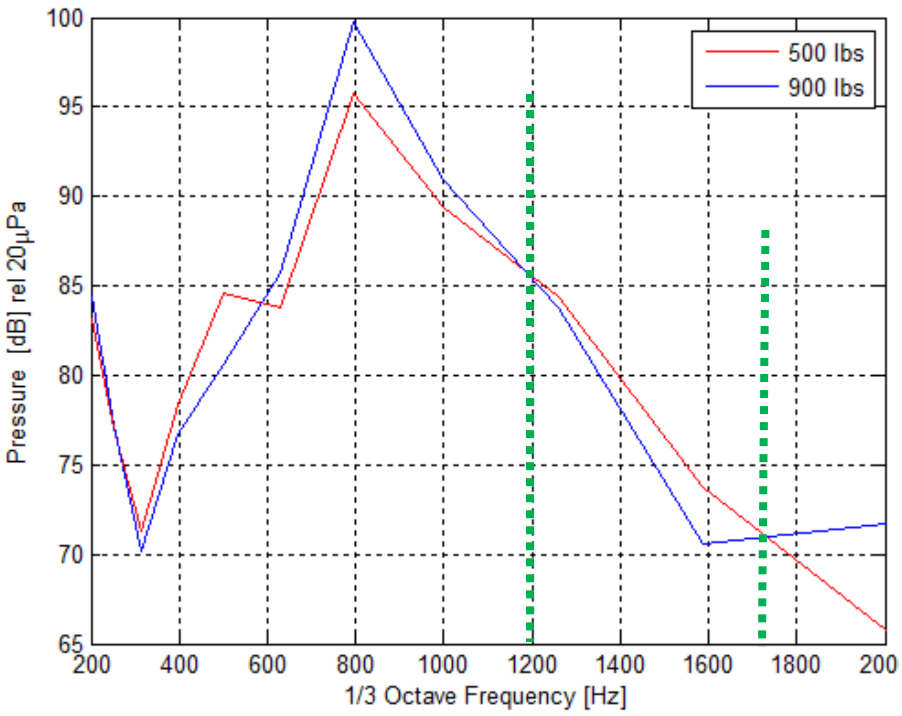
Pavement surface 1 (rough): Tire D fiber filled 1/3 octave levels



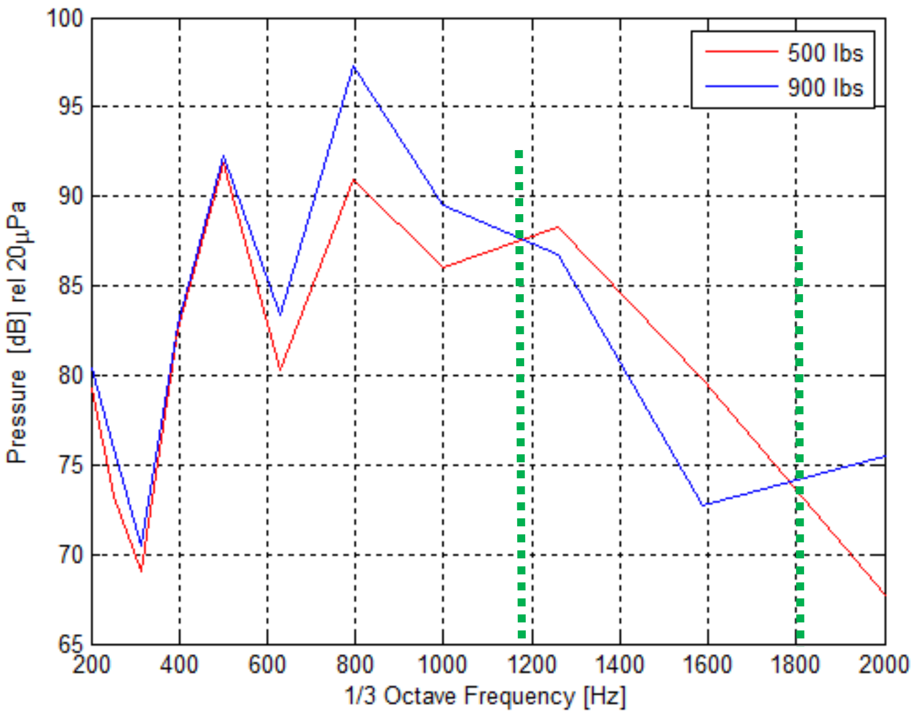
- ❑ Adding fibrous material did not eliminate load-noise reversal effect
- ❑ Spectrum level was reduced due to fibrous filling
- ❑ Reversal frequency range was slightly affected by the fibrous filling

IV. Results

Pavement surface 1 (rough): (a) Tire A and (b) Tire C (empty cavity)



(a)

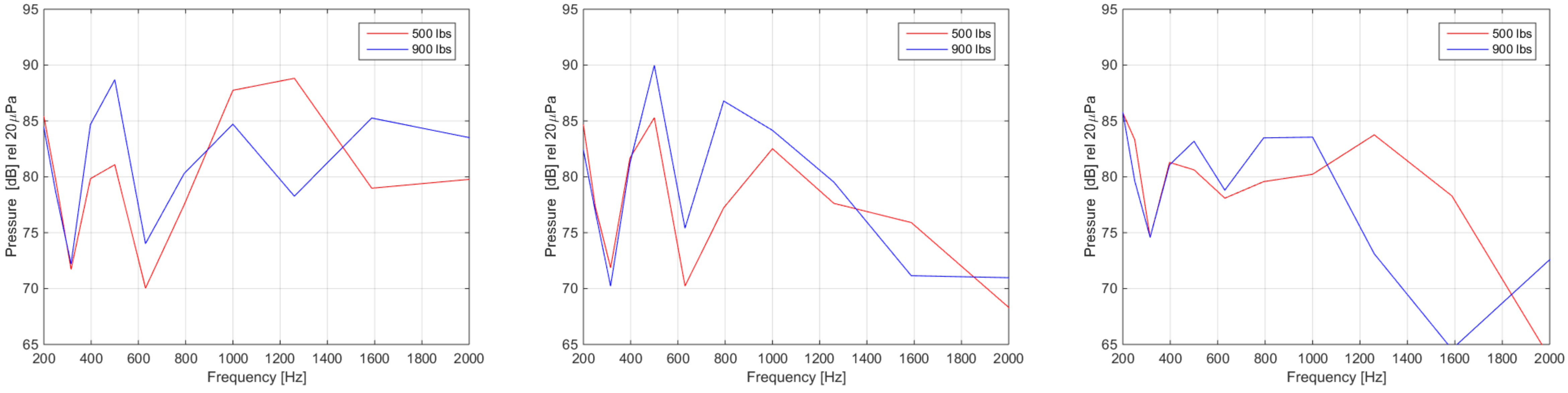


(b)

Load-noise reversal exist for other tires with different frequency range and levels

IV. Results

Pavement surface 3 (smooth): (a) Tire B, (b) Tire C and (c) Tire D. (Empty cavity)

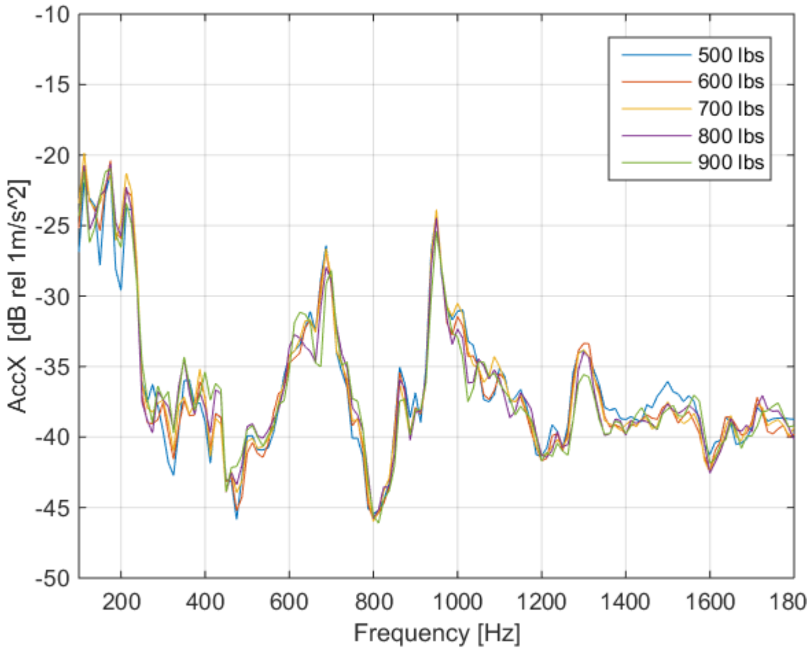


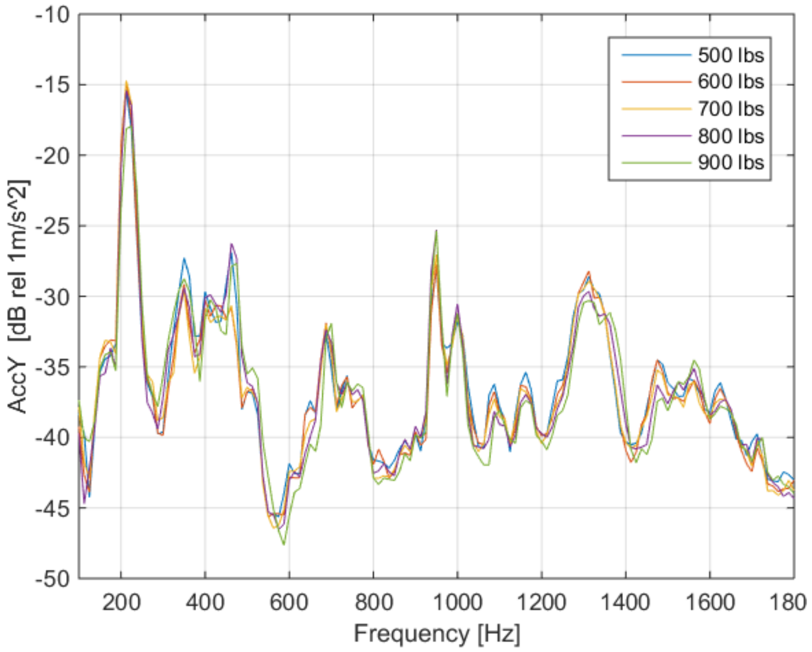
(a) (b) (c)

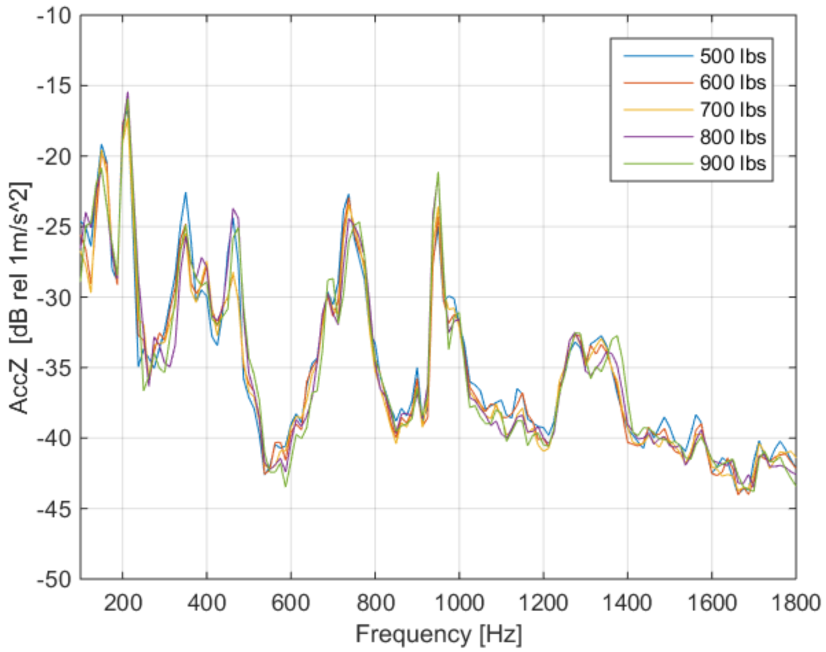
Load-noise reversal relation exists for all tested tires, but occurs over different frequency range between 1000 Hz – 1800 Hz

IV. Results

Pavement surface 1 (rough): Tire D acceleration in *x*, *y* and *z* directions



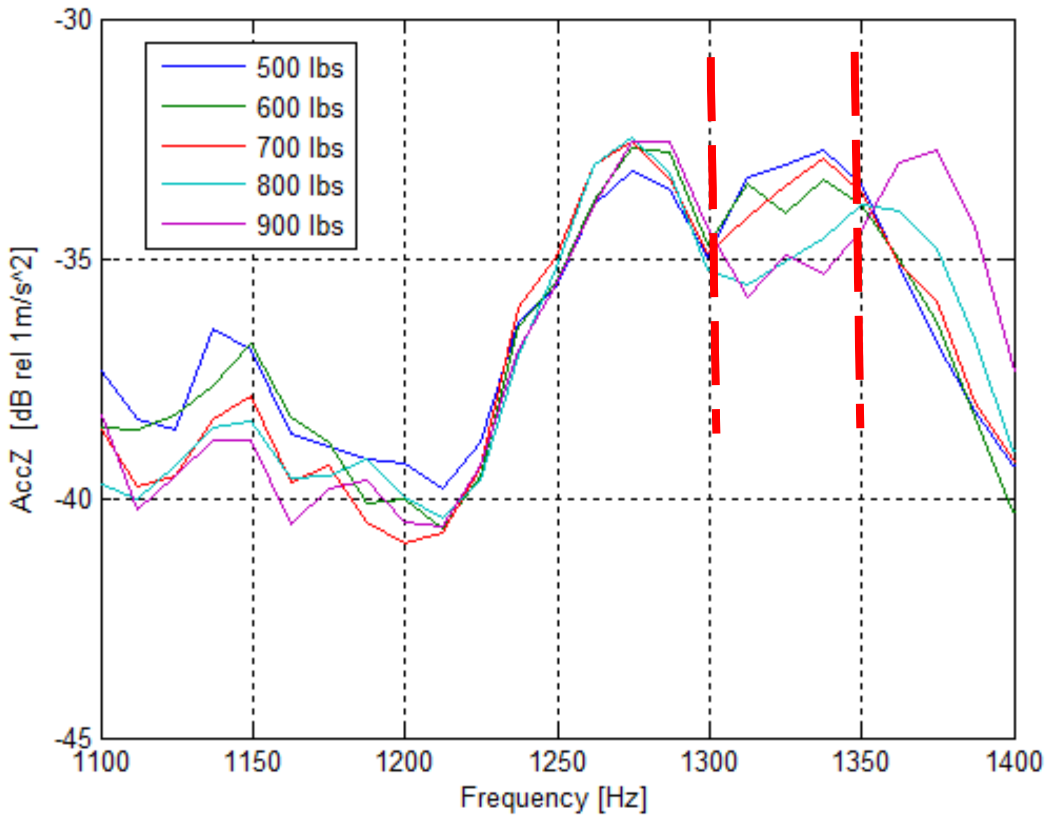




Not much vibration level difference exists in each direction for varying loads

IV. Results

Pavement surface 1 (rough): Tire D acceleration in *x*, *y* and *z* directions



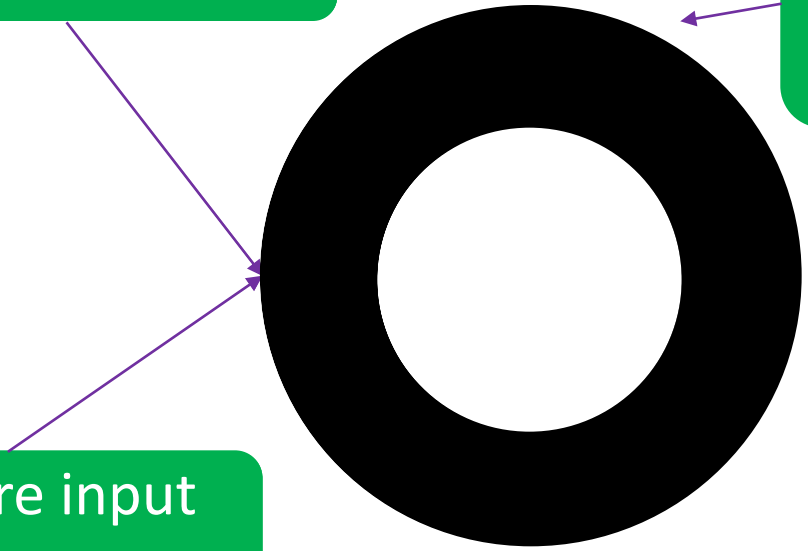
Around 1300 Hz, there is a peak where lower loads give higher vibration levels, although the difference is relatively small.
This could lead to load-noise reversal effect, but the motion associated with this phenomenon need to be identified

IV. Results

Possible structural motion responsible for this effect

Excitation

Measure surface velocity along the tire circumference



Measure input force

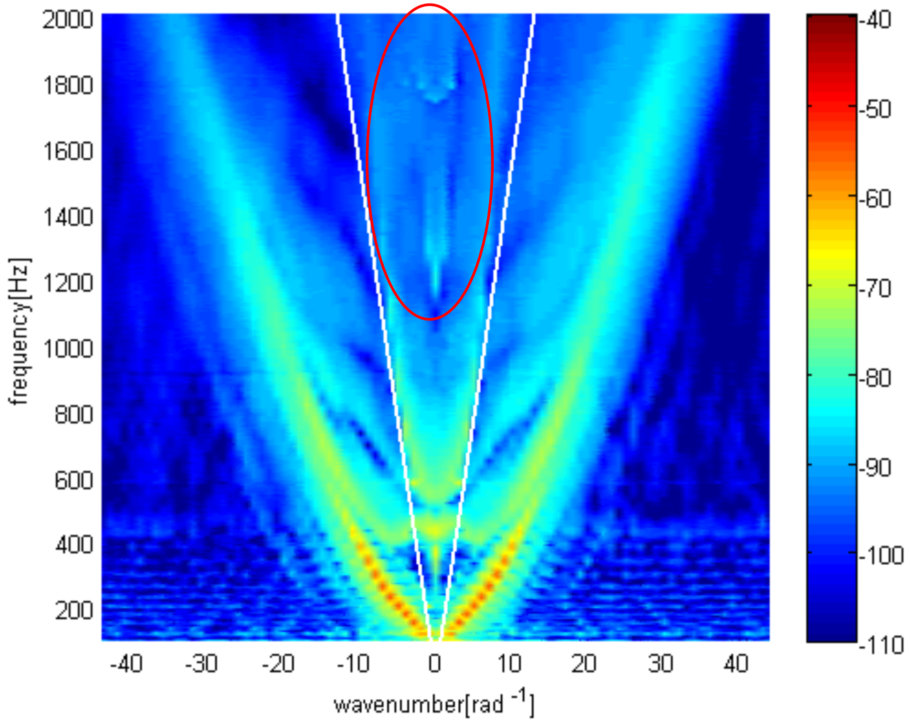
Wavenumber decomposition

Dispersion relation in the tire

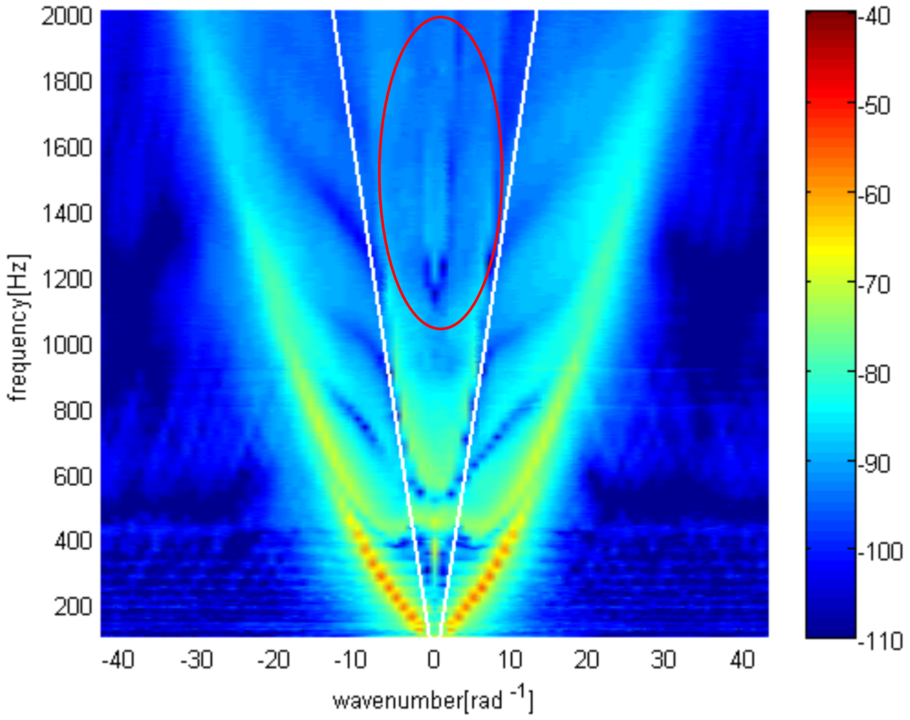
IV. Results

Possible responsible structural motion → **Dispersion relation**

Empty cavity



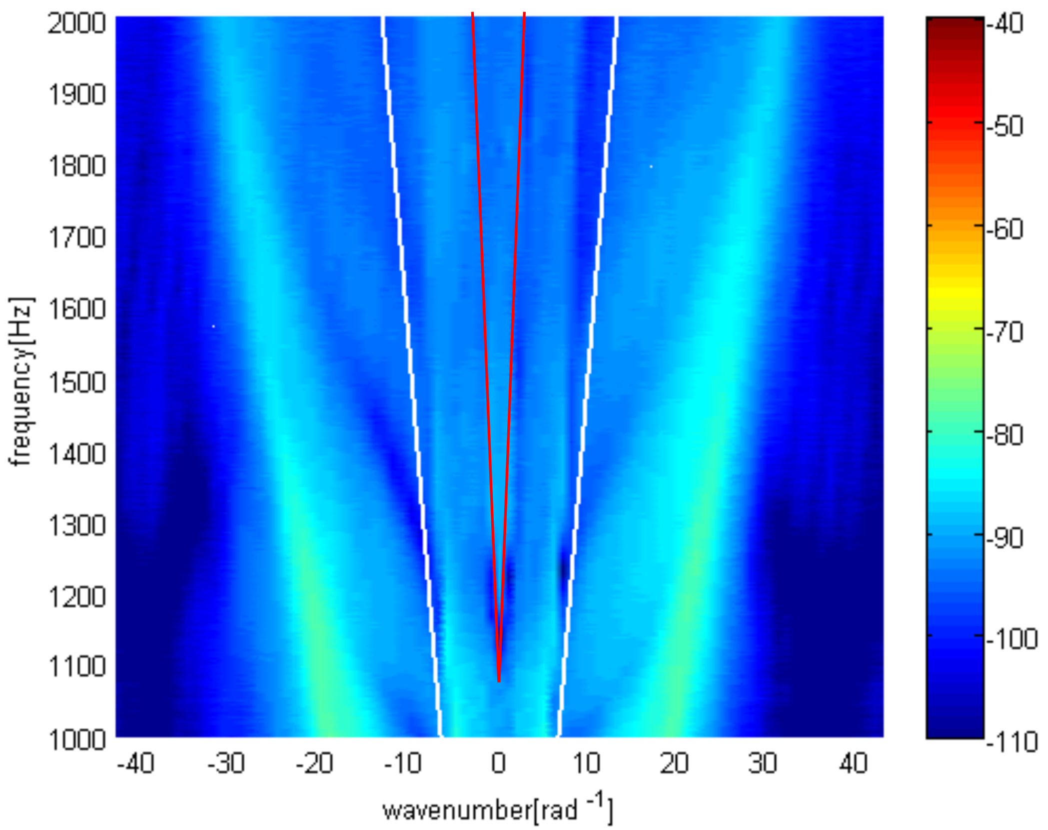
Fiber filled cavity



IV. Results

Possible responsible structural motion

Dispersion relation



Sound speed -340 m/s

Fast structure wave > 500 m/s

Supersonic wave has high radiation efficiency, which could be associated with bead to bead longitudinal wave, causing tire cross-section to expand and contract

V. Conclusions

- Increasing loading from 500 lb to 900 lb caused peak sound pressure levels to increase by 4 dB to 7 dB
- But in the 1.1 – 1.8 kHz region heavier loadings were always associated with lower sound pressure levels
- It is believed that an extensional wave that cuts on around this frequency that causes a deformation of the tire cross-section which is then very effective at radiating sound
- Occurs in frequency region where horn effect is significant, so possible significantly contribute to passby levels
- Possibly, the higher loading increases the stiffness of the tread and sidewall and thus makes it more difficult for the tire to deform
- However, further experiments and a high frequency finite element tire model are needed to confirm such suggestions